Ohio Agricultural Experiment Station

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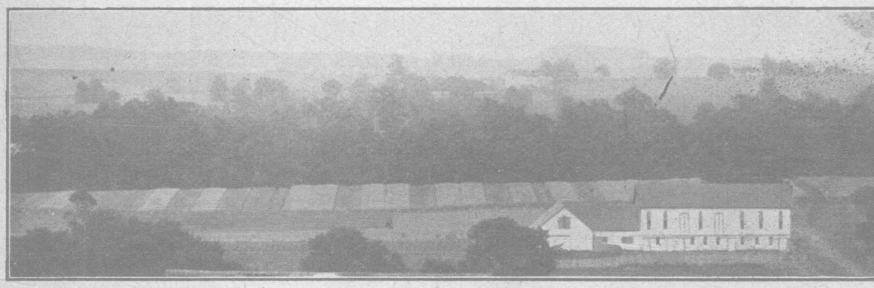


Section C, 5-year rotation, just before harvest.

PREFACE

The increasing interest which the farmers of Ohio are manifesting in field experiments, and the importance of so conducting such experiments as to obtain results which shall be useful and not misleading, are the reasons for the publication of this circular, which is, in the main, a reprint of a syllabus of an illustrated lecture, prepared a few years ago at the request of Prof. John Hamilton, Farmers' Institute Specialist of the Office of Experiment Stations, United States Department of Agriculture, for the use of Farmers' Institute lecturers. It is hoped that its suggestions may be found helpful to those who are entering upon this work.

CHAS. E. THORNE, Director.

ESSENTIALS OF SUCCESSFUL FIELD EXPERIMENTATION

By C. E. THORNE

INTRODUCTION

The experiment station is the distinguishing feature of the new agriculture. It stands for organized research in agriculture; for the concentration of the skill and energy of the entire State on the solution of the unsettled problems of the farm.

The experiment station is created to do things which are impossible to the ordinary farmer. It is furnished with costly equipment and conducted by men trained in the methods of scientific research, who are made free from other cares in order that they may devote their undivided energies to helping the farmer.

But while there are some things which can only be done by the aid of such an equipment as that of the experiment station, there are other things which the station can never do, and the farmer who profits most by the work of the experiment station is he who is himself an experimenter.

It is the province of the experiment station to discover and formulate general principles. The application of these principles must be made by the farmer himself. Even were there an experiment station in every county, there would still be hundreds of farms within each county on which some of the conditions would vary from those of the station, and while no farmer should attempt to duplicate the elaborate work of the experiment station, neither can any farmer afford to blindly accept the conclusions reached at the experiment station without subjecting some of them to the test of further investigation on his own farm.

Were there no other reason for this than the benumbing effect upon the intellect produced by the unthinking acceptance of the dicta of others, as evidenced by the unnumbered centuries during which the sickle remained unchangingly a chief implement of husbandry, this unchangeableness symbolizing a similar monotony in the farmer's intellectual processes, that alone would be abundantly sufficient. The farmer of today must learn to think or he is lost, and nothing is more conducive to exact thinking than scientific experiment.

The experiment station should carry its work far enough to demonstrate clearly the lines which practical application must follow, but after it has reached its uttermost limit there will still be much for the farmer to do.

Many experiments which farmers attempt, however, are either valueless or actually misleading, because of failure to observe some of the essential conditions of successful experimentation, for investigation in agriculture by experiment is a business by itself, entirely distinct from ordinary farming, and many a good farmer will overlook points of vital importance to the success of an experiment until his attention is called to them. It is in the hope of encouraging farmers to experiment more largely and to assist them in making their experimental work more effective that the following suggestions are offered.

SELECTION OF SOIL

A matter of first importance in preparation for field experiment is that the soil shall be as nearly uniform as possible in character. To secure such uniformity the following points should be considered:

GEOLOGICAL HISTORY

It is important, in experiments with fertilizers especially, to know whether a soil is of sedentary, drift, or alluvial origin; that is, whether it has been formed by the natural weathering of the underlying rock; by the action of the great glaciers, which once overspread the northern portion of the United States, grinding up the rocks over which they passed and rearranging their particles in the moraines and sheets of drift which they left behind them as they retreated northward, or by the action of flood waters of rivers and streams, washing down the soil from the higher lands and depositing it in the alluvial flood plains or "bottom lands" of the streams—a force which is in active operation today—as this knowledge may throw considerable light upon diffierent methods of treatment.

A sedentary soil is liable to be more uniform than a drift or alluvium, because in the case of transported soils there is generally a more or less uneven deposit of materials, an excess of gravel and coarse sand appearing in one spot and of silt and finer particles in another. A heavy sheet of drift may sometimes become weathered into practically the same condition as a sedentary soil, while it would seem that some of the great loess deposits would offer especially good conditions to the field experimenter, the loess being the fine-grained, silty soils found in some of the Western States, and whose origin is apparently due to the blowing of the dry surface dust into banks and hillocks, sometimes many feet in depth.

Fig. 1. Face of a stone quarry in a glaciated district, showing the heavy layers at the bottom, gradually breaking up into thinner layers toward the surface and finally ending in a finely broken stratum, over which is spread the thin drift sheet with its contained pebbles and small boulders. In many places in this region this drift sheet is replaced by a thin soil filled with the angular fragments of the underlying rock—such a soil as would be made by a little further disintegration of the upper stratum of rock shown in the picture.

PREVIOUS MANAGEMENT

It is also important to know something of the previous management of the soil. The great Rothamsted experiments have shown the persistence of the effect of applications of barnyard manure—the yield from a formerly manured plot remaining more than double that of the unmanured land alongside for thirty years after the manuring had been discontinued. Other illustrations are given to show the effect of leaving fence rows or lanes uncultivated for a period of years and then bringing them into comparison with lands brought under cultivation at an earlier date. Again, a tree which has stood for years after the remainder of the forest has been cleared away, and whose shade has been a resting place for live stock, may cause a considerable variation in the productiveness of the soil which will be manifest long after it shall have been cut away. These points are clearly shown in Figures 2 and 3.

Fig. 2. Showing the growth of corn on an old roadside fencerow, in a region where the discovery has recently been made that it is cheaper to fence cattle in than to fence them out, and consequently the fences are being limited to such as are necessary to inclose permanent pastures, and many miles of road are entirely unfenced.

TOPOGRAPHY

Absolutely level land is seldom adapted to field experiment, for the reason that no land is so flat that it does not have slight inequalities of surface and on such land the minor depressions receive a larger share of the rainfall by surface drainage from the higher portions, and thus have an advantage in dry seasons when water may be the controlling factor in producing increase of crop, while they may be at a disadvantage in seasons of excessive rainfall. When the subsoil is porous these depressions may merely be a little more fertile than the higher portions through increased accumulation of humus, but if the subsoil be impervious to water it may give rise to a semiaquatic growth of vegetation which may radically modify the behavior of the soil under cropping. On the other hand, steep hillsides are not adapted to experiment, because the water from heavy rainfalls in washing over them will cut them into gullies or transport fertilizing materials from plot to plot.

The ideal topography for field experiment is a broad, gentle slope of about 1 to 2 percent, or just enough to permit the surplus water of heavy rains and melting snows to flow off uniformly and completely.

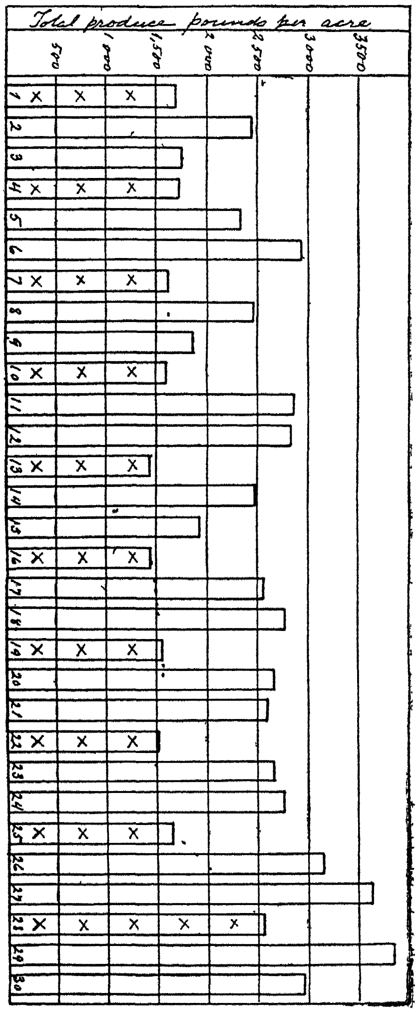


Fig. 3 Diagram showing the yield of the unfertilized plots in an experiment in which corn, oats, wheat, clover and timothy have been grown in a 5-year rotation for ten years. There are thirty plots in the series, and every third plot, beginning with No. 1, has been left continuously unfertilized. The average yield of these plots ranges between 1,400 and 1,750 pounds per acre until No. 28 is reached, when it suddenly mounts to 2600 pounds This experiment was located in a field which had been in cultivation for fifty years or more, and at the time it was laid out in plots no difference was apparent between the land occupied by Plot 28 and other portions of the field; but it was afterwards learned that this plot and parts of the adjacent plots had been occupied by a lane until some seven years before the test began.

ROTHAMSTED EXPERIMENTS, HOOS FIELD

Barley 51 years in succession on the same land.
Produce, without manure and with farmyard manure.

	Bushels per acre	
	First 20 years, 1852-71	51st season, 1902
Unmanured every year	19.9	12 7
Manured every year first 20 years, last 31 years no manure	48.2	27.5

ARRANGEMENT OF PLOTS

SIZE OF PLOTS

Farmers generally have the idea that experiment plots should be made as large as possible, an idea naturally following their observation of the inequalities of most soils; but the practical difficulty in the way of using large plots is the fact that for a comparative experiment the soil must be as nearly absolutely uniform as possible, and it is extremely difficult to find large areas having sufficient uniformity. In almost all cases it will be found better to use a large number of small plots than a small number of large plots, since by multiplying the plots the variations of the soil can be more evenly distributed. A field of ten acres, for example, in which it is desired to make ten comparisons, will yield results of far greater value if cut into 100 plots containing one-tenth acre each, giving ten plots, distributed over the field, to each particular comparison, than if only ten plots are employed.

The most convenient size of plots for computation is one-tenth acre. When the plots are reduced much below one-tenth acre in size another element enters into the problem, namely, the individuality of the plant. One-tenth acre of corn, as usually planted, will contain nearly a thousand plants, and this number might be grown from a single seed ear; but experiments have shown that ears taken from the same variety and grown on neighboring stalks may vary 50 percent in their produce. Hence, even for plots of one-tenth acre, the greatest care should be taken to secure seed which has been drawn from a considerable number of ears and thoroughly mixed. In the case of wheat or oats a tenth-acre plot may contain from 100,000 to 150,000 plants, the seed of which has probably been obtained from 3,000 to 5,000 heads of grain, representing several hundred separate plants. Hence, we may safely use a smaller plot for the small grains than for corn.

Fig. 4. Part of a field of about sixty acres which is wholly devoted to plot experiments. It slopes gradually toward the north with secondary slopes east and west, which give sufficient fall for the lateral tile drains that are laid between the plots, running east and west and emptying into mains which run north, one on each side of the field.

SHAPE OF PLOTS

It is generally conceded that experiment plots should be long and narrow, both for greater convenience of cultivation and also because this shape permits a better arrangement with respect to irregularities of soil. The minor inequalities of the soil are usually caused by the gradual washing of the surface into small ridges and valleys, which can be so crossed by a long and narrow plot as to cover equal portions of the lower and higher land, whereas this would not be so readily accomplished in square plots. It is well to adapt the width of the plot to that of the machinery in use. A plot 16 feet wide, for example, will contain four rows of corn four feet apart, or five rows of potatoes 38 inches apart. It may be sown with three "throughs" of an 8 hoe, 8-inch drill, and cut in three swaths with a machine having a 5½ or 6-feet cutter bar. The width of the plots should be adjusted to the drainage. When they are more than 16 feet wide it will be necessary on most soils to give each plot a separate drain.

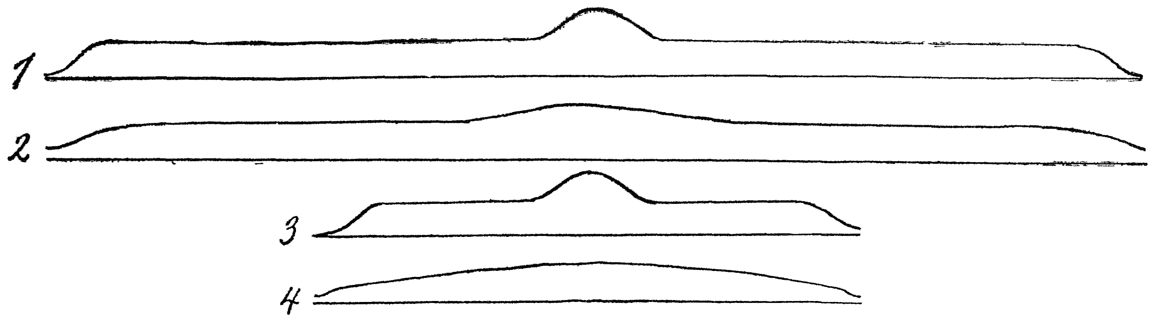
SURFACE DRAINAGE

Whatever the natural topography may be, under most circumstances the uniform disposal of excess of surface water may be facilitated by a slight ridging of the plots, which may be accomplished by plowing the plots separately. To attain this end successfully the plots should be comparatively narrow, in order that the cross harrowing may so distribute the ridge left by the plow as to leave a gradual slope from the middle of the plot to the sides. On wide plots there will always be a flat space left between the ridge and the furrow.

It is not necessary nor advisable to repeat the ridging at every plowing. On the contrary, the effect of ridging will remain apparent for five to ten years, even though subsequent plowings and cultivations be, as they should be whenever practicable, across the plots.

CROSS DRAINAGE

One of the chief objects in separating the plots by dead furrows is to prevent cross drainage of surplus rainfall. Where there are no surface drains such water will, of course, follow the natural slopes of the land, and these are practically never sufficiently regular for the purpose of plot experiment. In variety testing and cultural work this may not always be a matter of great importance, but in fertilizer tests it is essential that the fertilizer applied to each plot be confined to that plot, which can not be the case if the surface water is permitted to flow indiscriminately across the plots.



EFFECT OF RIDGING ON WIDE AND NARROW PLOTS.

Fig. 5. No. 1 shows a plot two rods in width as first plowed, and No. 2 shows the same plot after the harrow has gone over it, partly leveling the ridge or back furrow. Nos. 3 and 4 show a plot one rod wide under similar conditions. It will be observed that in the narrower plot the effect of cross harrowing is to leave a surface having a gradual slope from the crest to the furrow, whereas on the wide plot there will be a flat space left between the two. The practical difference between the two methods of plotting is that the surplus water of heavy rains and melting snows will flow off the narrow plot more uniformly and with less washing and gullying than off the wider one.

Fig. 6. Contour of plots 18 feet wide from center of furrow as obtained in actual practice. These plots have just been ridged for the third time in twelve years. Future crosswise plowing will materially reduce the height of the ridges.

Even in such work as variety testing, however, it is desirable that the surface water find it way off the plot as quickly as possible. If it stands in minor depressions over the plot it will cause irregularities in yield; if the plots are laid off up and down a slope the water will follow down the drill rows, washing out many plants during the spring thaw, while if the plots are laid off across the slopes there will be cross washing which, in fertilizer comparisons, will vitiate the results. The best arrangement in such work is to so ridge the plots that the surface water will flow from the middle down the sides of the plots into dividing furrows, these being so graded as to carry it away. Some gullying of the furrows is almost unavoidable, but it is better there than within the plot itself.

CROSS FEEDING

Another prime object of a furrow between the plots is to prevent cross feeding—that is, the extension of the roots from an unfertilized plot, for instance, to one that has been fertilized—and this is practically accomplished by the ordinary dead furrow.

UNDERDRAINAGE

Provision for the removal of an excess of soil water is absolutely essential to successful field experiment. Such excess may be naturally removed by stratified rocks lying at shallow depths below the surface, or in rare instances deposits of gravel may be found sufficiently uniform to serve this purpose, but in the vast majority of cases, especially with soils that have been so long in cultivation that a hardpan has been formed, it will be necessary to aid nature by artificial drainage.

In draining for plot experiment the drains should be so located as to give uniform drainage to each plot. When the plots do not exceed a rod in width and the soil is reasonably porous, a single drain may serve two plots, being located under the division space between them, but in the majority of cases it would be better to give each plot its separate drain, located either under the dividing space or under the middle of the plot. The former location is probably the better one where it is not designed to study the composition of the drainage waters, as the surface waters accumulating in the furrow will be more promptly removed if the drain lies immediately beneath the furrow than if it lies under the middle of the plot.

Figure I presents a good illustration of conditions for natural underdrainage. As stated in the description of the cut, there is a gradual transition from the heavy layers of stratified rock, through the lighter layers and broken strata to the thin sheet of soil, which has been formed by the slow weathering of the surface rock, aided by the action of ancient glaciers. On this soil trees are growing which send their roots through to the rocks below. When the trees are cut away their decaying roots furnish natural drainage channels to the rock seams below, but these channels are gradually obliterated by the scraping of the plow and the trampling of the teams and grazing stock. Eventually the subsurface becomes so compact as to greatly retard the percolation of the surface water, and artificial drainage becomes necessary.

DIVISION SPACES

Division spaces two feet in width have been found sufficient for the separation of the plots, even in fertilizer tests, provided the land is plowed in ridges with the dead furrows falling at the division spaces. Such narrow spaces necessitate special care in seeding in order that the grain may not be sown too far down in the furrow. The dead furrow is rightly named, and in proportion as the seed falls within its influence will the growth of the plant be diminished. When the division space is not more than two feet wide and the planting is accurately done, the resulting produce will probably be a more accurate index of what might be expected under ordinary field culture, under the same treatment, than where the spaces are wider, as in the latter case the outside rows will have a larger area for root extension, before reaching the dead furrow, than in the former.

OLD RIDGES AND DEAD FURROWS

It is of prime importance to so arrange the plots as to avoid the errors arising from old ridges and dead furrows, for either a ridge or a furrow, running lengthwise in a plot, may completely reverse the results of the test. Wherever possible, experiment plots should be laid out across the direction in which the field has previously been plowed.

CHECK PLOTS

A matter of great importance, too often lost sight of in field experiments, is the repetition of check plots. In the most uniform soils there will be some variation in the produce of adjoining plots from season to season. Even were the actual plant food the same, the variations in level which occur on all soils will produce an unequal distribution of moisture, and moisture may often be a more important factor in determining crop yield than plant food. The ideal system of plot experiment would leave every alternate plot as a check. Next to this comes the plan of leaving every third plot as a check, thus having a check plot on one side or the other of every plot under treatment. In fertilizer tests the check plots may be unfertilized or subjected to uniform dressings with a standard fertilizer or manure, depending upon the object of the experiment. In variety tests the check plot should be planted to a standard variety. The importance of repetition of check plots will be further illustrated under the head of calculating increase.

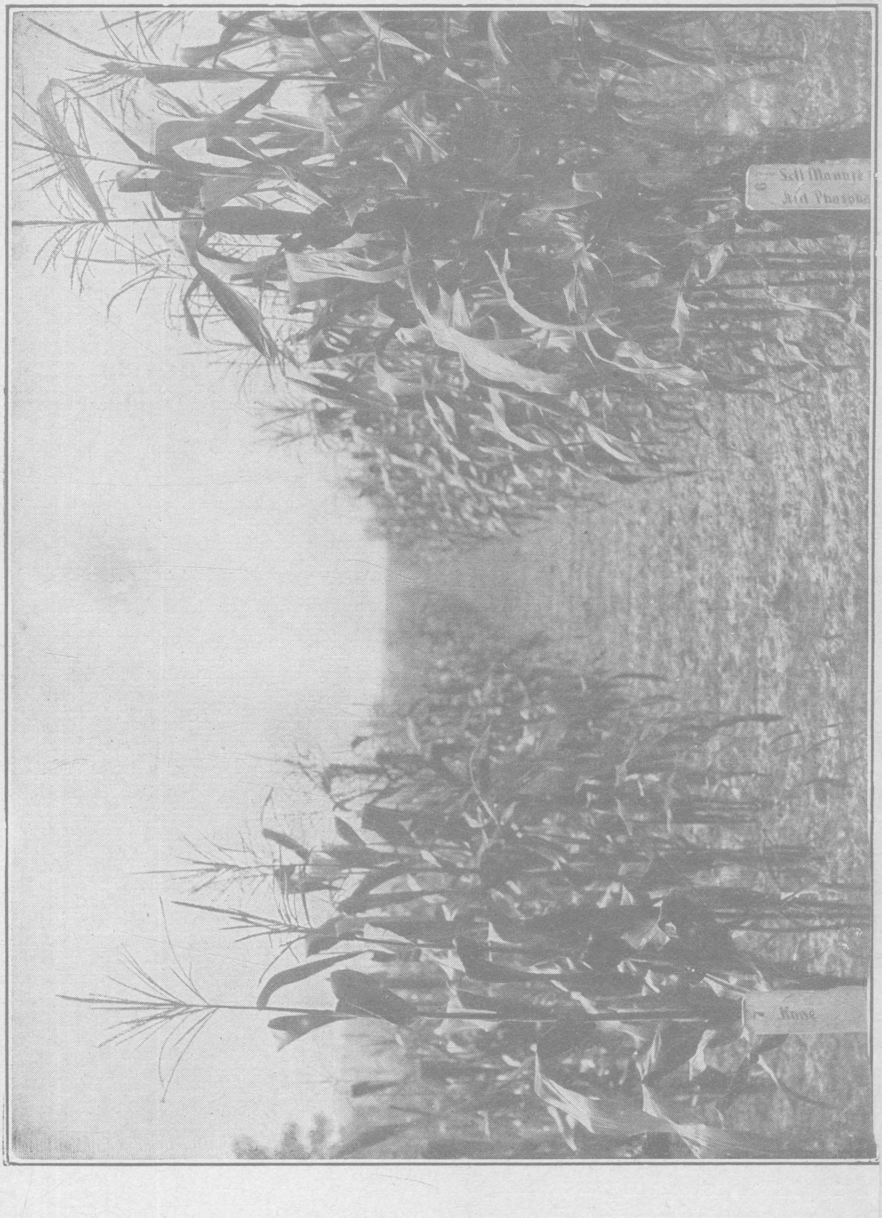


Fig. 7. Two feet wide dividing space between plots of corn.

Fig. 8. Two-feet wide dividing space beween plots of oats.

...the ridge or back furrow formed by throwing two furrows together. It will be seen that if one plot has such a
Fig. 9. The middle row of corn ... apparent results of a comparative test may be very misleading. The effect of an old dead furrow may be equally as fatal to accuracy in
back fu...

PERMANENT BOUNDARIES

A plot of land designed for experiment should be definitely marked with permanent stakes, especially if tests with fertilizers are to be made. A very convenient marking stake for such purposes is a piece of second-hand gas pipe, about two feet long, driven to such a depth that harvesting machinery will pass over it. A block of, say, ten plots may be marked with such stakes, set at the corner of the block, the intervening distances to be measured for each planting.

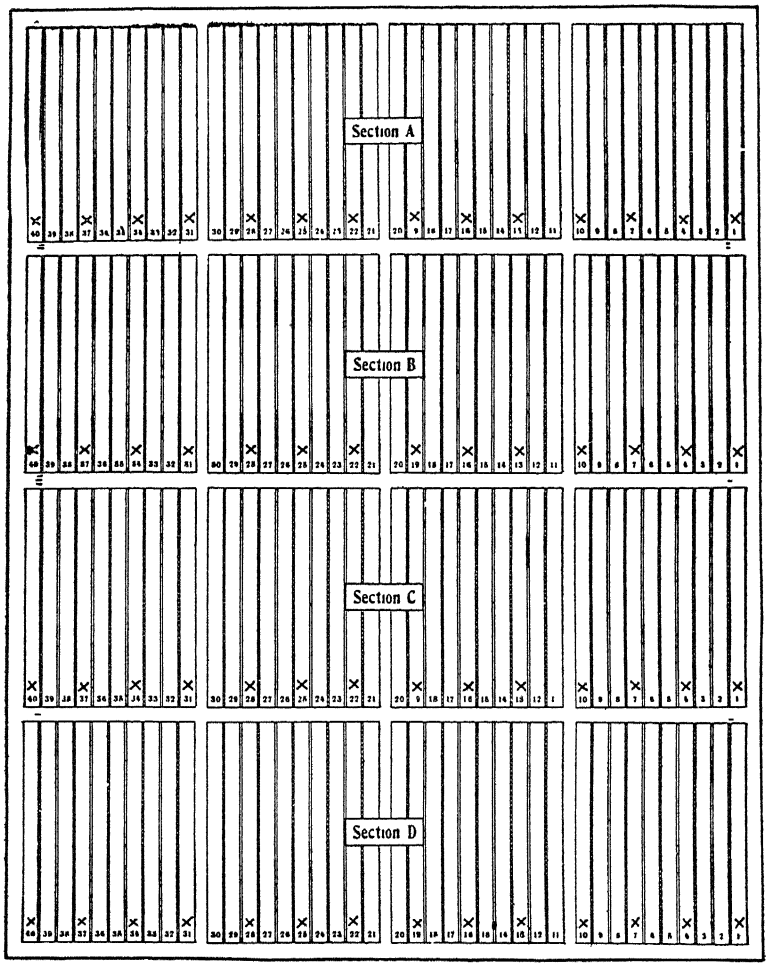


Fig. 10. Four ranges or tiers of plots, 40 plots each, as actually employed in an experiment in in which corn, oats, wheat and clover are grown in rotation, each crop being grown each year. The plots marked X are check plots.

HEADLANDS AND ROADWAYS

Ample headlands should be left across the ends of every block of experiment plots. Not only are these headlands needed to prevent the breaking down, in turning while cultivating, of such crops as corn or potatoes, but they are required in the harvesting of the small grains, in order that the machine may be driven around the plots empty, and they are even more urgently needed in plowing, as the trampling of the soil by the team in turning the plow will materially affect the yield of the following crop. These headlands may be made 18 feet wide, but 20 feet is better.

In addition to the headlands there should be roadways at intervals through every large group of plots, to permit the first passage of the machine in harvesting, or the continual passing where it is necessary to cut the grain but one way, and the passage of wagons in hauling manure or grain. An experiment plot should never be used as a roadway, for the reason given above, that the additional trampling and packing by the teams and wheels, even in the driest weather, will so change the physical condition of the soil as to affect the future yield of crops. A convenient arrangement, where the plots are not more than 16 feet wide, is to leave a 12-feet roadway between blocks of eight or ten plots. These roadways may be planted to the same crop as that grown on the plots, the roadway to be cut out and the produce set to one side where it will not be mixed with that of the plots before the harvesting of the plots is begun.

The headlands, however, should be kept in grass, in order that the plots may at all times be accessible. Nothing will add so much to the interest in and value of an experiment as to be able to visit it at any time and to see clearly the contrast between plots. It is not waste, but economy, to give a little land to this purpose.

LABEL STAKES

Every plot should be distinctly marked with a label stake, giving the number of the plot and an indication of its treatment. A very convenient stake for this purpose is a board four inches wide and 30 inches long, sharpened at one end, painted with three coats of white-lead paint, and lettered with price markers or with brush. Such stakes, if taken up and sheltered through the winter, will last ten years or more.

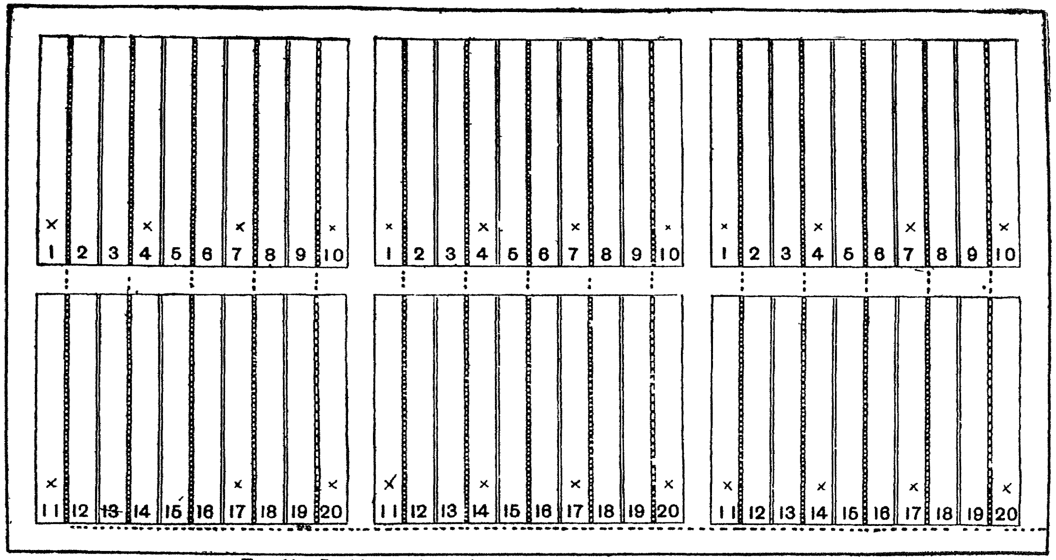


Fig. 11. Six blocks of ten plots each, arranged for a 3-year rotation.

PREPARATION OF LAND FOR CROPS

UNIFORM PLOWING

It is highly important that the plowing and fitting of the land for a comparative experiment be as uniform as possible in every respect. A difference of a few weeks in date of plowing may cause as great a difference in yield of crop as will be produced by difference in fertilizing, and far greater than is usually observed between varieties. For this reason the plowing should, as a rule, be done across the plots, and when it becomes necessary to plow the plots separately, in order to ridge them, the work should be pushed forward as expeditiously as possible. On this account it is well to have the plots arranged in blocks of ten, planning the test so that each block will have its complete series of checks, independently of the others.

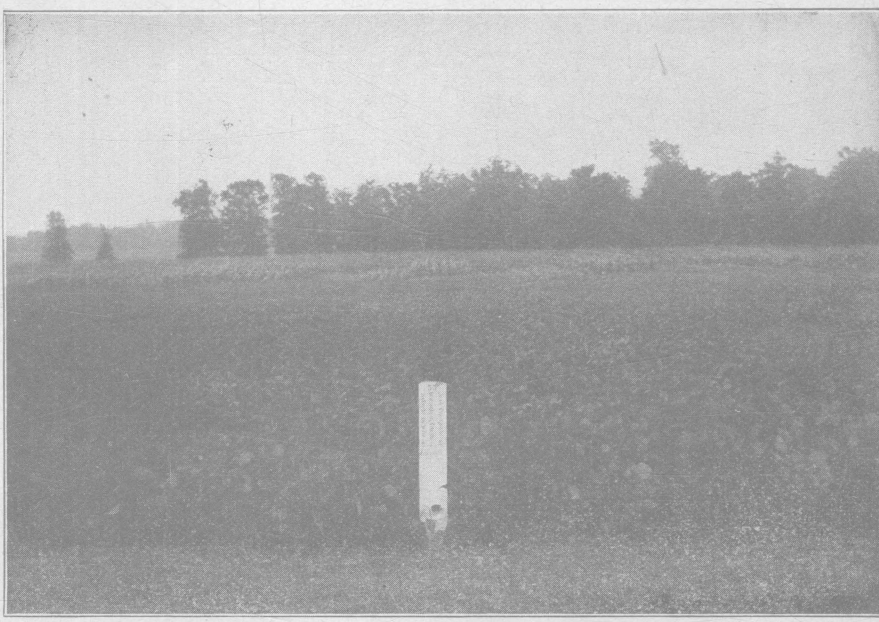


Fig. 12. A convenient label stake four inches wide by 30 inches long, painted white and lettered with a brush. These label stakes are useful but should never be permitted to take the place of a carefully written record or diagram, as stakes may be easily transposed or lost. The stake should be so lettered as to show the number of the plot at which it stands, and also the kind and amounts of fertilizer applied to that plot.

MANURING AND FERTILIZING

Both manures and fertilizers may be distributed by machinery more uniformly and accurately than by hand. In a comparative test of manures or fertilizers it is important that the material be kept entirely on the plot, leaving the dividing spaces entirely untouched; but where the test is one of varieties or methods of culture the entire surface may be covered. In applying fertilizers it is a good plan to bring the applications intended for the different plots all to the same bulk, by mixing them with dry sand, so that a single setting of the drill may suffice for the entire experiment. Even then it will not always be possible to exactly gauge the material, for mixtures which are largely made up of such salts as nitrate of soda and muriate of potash will pass through the drill less readily than those which contain a larger proportion of sand. It is a good plan to test the drill by sowing an equal bulk of material on a plot not designed for experiment before beginning the actual work. The fertilizer will run more slowly as the drill becomes nearly empty; hence it is well to set the drill so that a little will be left in it after the plot has been gone over, and then turn back over the work until all is out.

Machines are now made for distributing fertilizers and lime broadcast. They are made wider than the ordinary fertilizer drill and are guaranteed to spread even slaked lime satisfactorily. Where such a machine is not available, the manure spreader may be used for lime spreading, first spreading a layer of chaff or similar material in the bottom of the machine and spreading the lime on this. Where small quantities of lime are to be applied—1,000 pounds or less per acre—it will be an advantage to gear the machine so that the apron will travel more slowly than in ordinary work. The best manure spreaders are now fitted with hoods and slow gearing for lime spreading.

MACHINES SHOULD BE ACCURATE

While a good machine will do better work than can be done by hand, there are many machines in use which are not fit for experimental work. There are both corn planters and grain drills which do not distribute the grain uniformly, while there are others which are unsuited to the experimenter's purpose because they are too difficult to clean out, thus greatly increasing the difficulty of making variety tests. In thrashing, this last difficulty is still more conspicuous. The modern thrashing machine is gotten up at a low cost and intended only for rapid work on a large scale, and is altogether unsuited to the separation of different varieties of grain. The older thrashing machines, with the traveling apron, are better adapted to this work than the modern machine. There should be no place for grains to lodge in passing through the machine, but it should be so constructed that every grain entering the cylinder will be promptly carried through the machine and out at the proper place. It is possible to do this, but of course the cost of the machine will be increased.

Fig. 13. Showing a sign board for the convenience of visitors. This sign board should show the nature of the experiment by indicating the length of the rotation and the kind crops grown, etc.

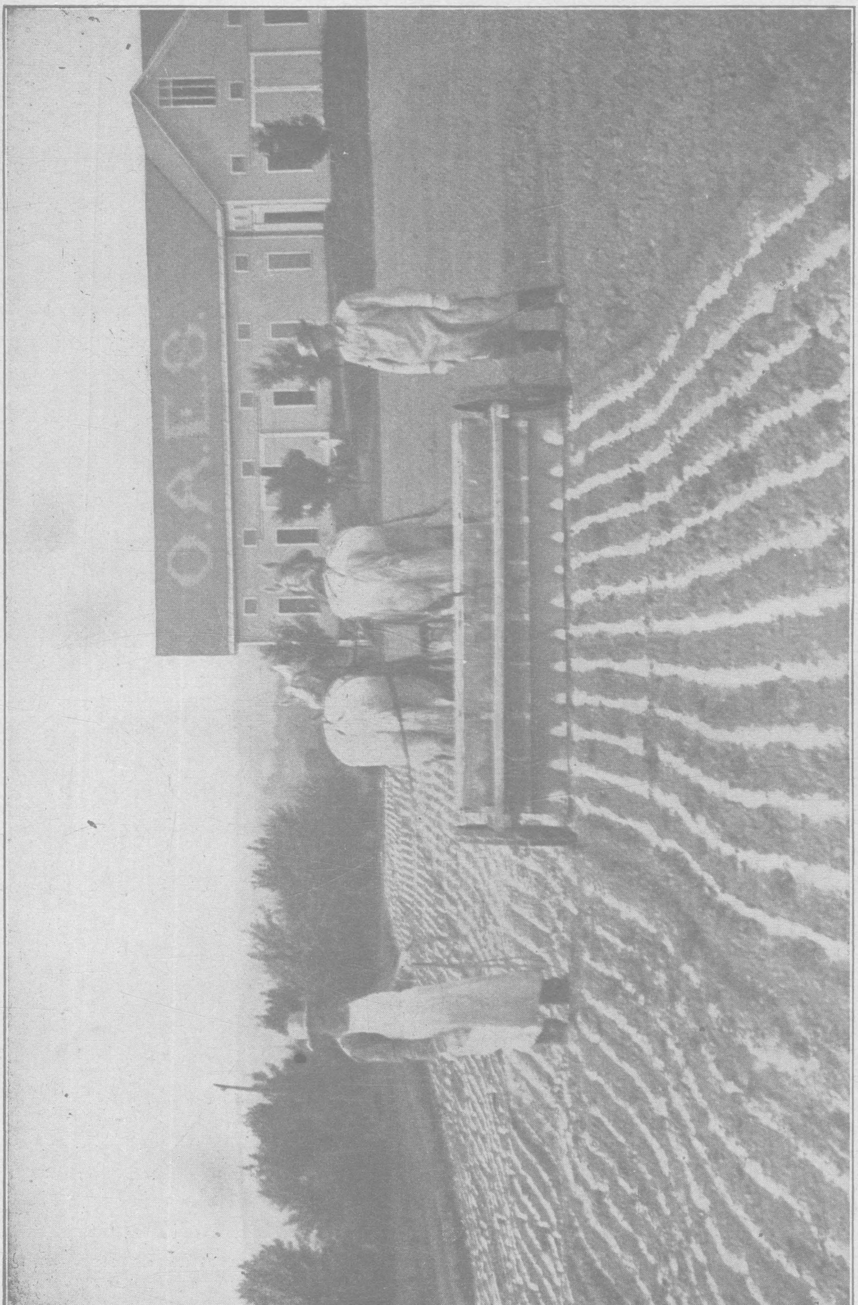


Fig. 14. Distributing lime with a lime spreader This implement is much to be preferred where lime is used in any considerable quantity.

SELECTION OF SEED

The selection of seed is a very important matter in field experimentation. Defective seed means an imperfect stand, and an imperfect stand means an unreliable experiment, for no method of calculation yet known will correct the inequalities of an irregular stand. Not only should the seed be strong in vitality, but it should be uniform in size, because such uniformity not only is necessary to uniformity in distribution by machinery but also to uniformity in growth of the young plants. For this reason the seed corn should be selected from the middle of the ear, rejecting the butts and tips, and wheat and oats and other small grains should be carefully graded by passing them through a fanning mill and over a sieve, which will take out the small and imperfect grains.

THE ROWS SHOULD BE STRAIGHT

That rows should be straight applies even more forcibly to the small grains than to corn, for a careless driver who allows his rows to run together by so much reduces the yield of the plot, as experiments have shown that where the quantity of seed passes above a certain maximum—and the regular seeding should be near this maximum—then the yield falls off; so that when two rows run together not only do we lose all the produce of one of the rows but part of that of the other.

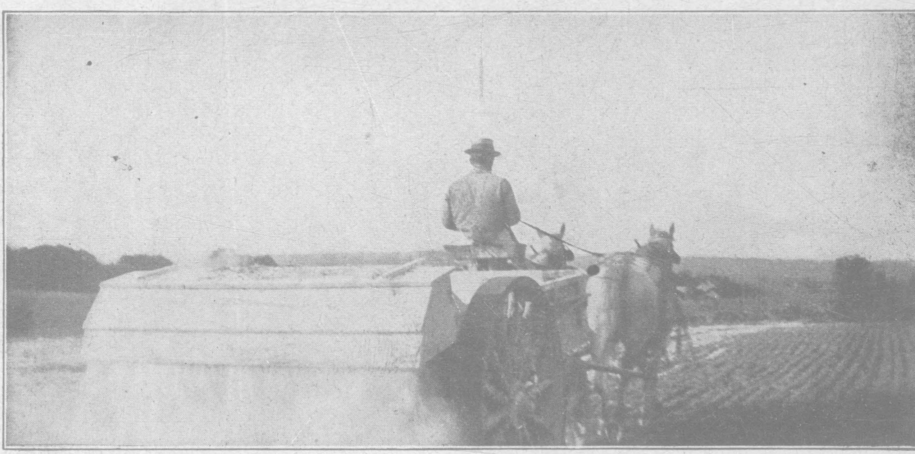


Fig. 15. Distributing lime with a manure spreader. This is the best substitute for the special lime drill which we have. By spreading litter of some sort over the apron and putting the lime on this, and by using the hood, as shown in the cut, we can get a fairly satisfactory application of the lime, although the work will be found to be much more dusty and tedious than with the special lime spreader.

THE ENTIRE PLOT SHOULD BE PLANTED

In drilling the small grains most drills will travel a short distance before the seed reaches the ground. If the drill is started at the exact end of the plot, therefore, there will be a short space unsown. To guard against this the drilling should extend beyond the ends of the plots, the excess being cut away before the plot itself is harvested. The best way to accomplish this is to stretch a line between the stakes marking the corners of a block of plots, and with a hoe cut out a narrow strip under the line. The nose of a machine may then be made to follow this strip, thus quickly cutting away the excess, which of course must be kept out of reach of those who haul in the grain, if the trimming has been left until harvest time, but the better way is to trim the plot ends while the crop is still green, making hay of the produce. Not only will this method remove all danger of mixing the results, but it will add to the satisfaction of watching the maturing of the different plots.

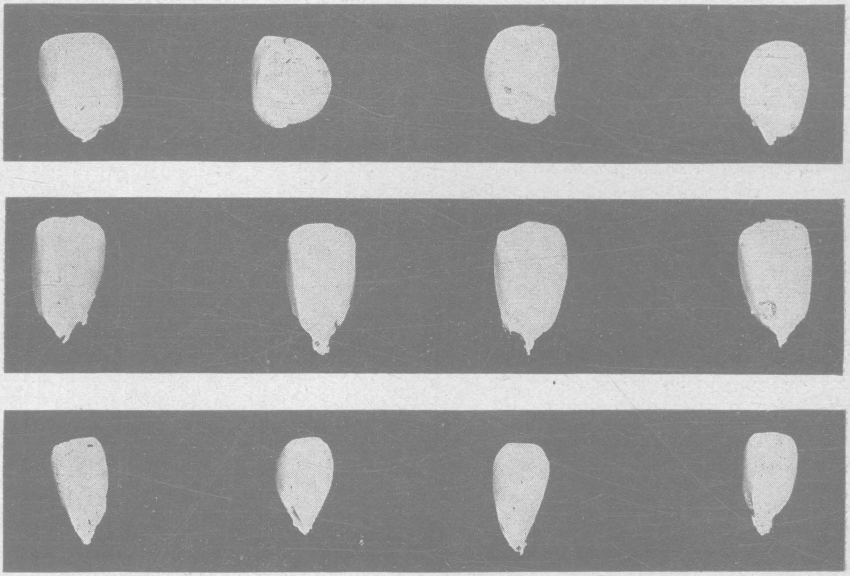


Fig. 16. Four grains of corn each from butt, middle and tip of the same ear, showing difference in size.

PLANTING AND CULTIVATION

MACHINE WORK PREFERABLE

Wherever possible machinery should be used in planting and cultivating. There is no longer any question as to the superiority of drilling the small grains over sowing them broadcast, and the same principles apply to the corn planter, at least, if not to the potato planter. Certainly they do to the tobacco planter. The seed grain is deposited more uniformly by the drill or planter, whether as to quantity of seed, depth of planting, or uniformity of covering, than can be done by hand. Even the hand corn planter is better than dropping the seed by hand and covering with the hoe, while a man and two boys will set tobacco or cabbage plants not only very much more rapidly but also much better with the machine on which they all ride, carrying with them a barrel of water which automatically deposits a cupful at uniform distances in the row, the boys alternately placing a plant in the freshly opened furrow just as the water reaches it, while the machine closes the furrow and presses the earth around the plant.

In cultivating, and especially in harvesting, machinery is essential to rapid work. An experiment with cereals is incomplete unless the proportion of straw or stover to grain is determined, and it is practically impossible to secure uniformity of stubble, either of small grains or corn, by hand cutting.

In thrashing the small grains no one would now think of using the flail where it was desired to make an accurate determination of the separate product of straw and grain. With corn, however, thrashing machinery has not yet reached a stage at which it can successfully compete with hand husking.

HARVESTING

CUTTING GRASS PLOTS

In experiments with crops grown in rotation the grass and clover crops usually occupy the dividing spaces, as well as the plots proper. A convenient and fairly accurate method of harvesting such plots is to drive the machine to stakes, so set that the point of the machine will just reach the outside of the plot. A careful driver with a steady team can thus cut a swath as straight as though a line had been stretched. After the outsides are thus cut, the cutting out of the middle is a simple matter. The dividing spaces should be left uncut until the hay has been taken up from the plots.

HARVESTING SMALL GRAINS

When plots of small grain are arranged in blocks, as has been above recommended, the roadways are first cut out, the ends of the plots straightened, if this has not been previously done, after which, if the grain be not lodged, the machine may cut up one side of the block and down the other, running empty across the ends, of course, but a man should follow the machine to remove the residue that may be left on it as it leaves the plot and to see that each sheaf is finally left on the plot to which it belongs.

HARVESTING CORN

The corn harvester will no doubt come into general use because of its great saving in labor and because of its uniform stubbles, but in experiment work it is indispensable that a gleaner should closely follow the harvester in order to pick up dropped stalks and ears which may be broken off and keep them on their proper plots.

HARVESTING POTATOES

Potatoes may be harvested with the potato digger with a fair degree of accuracy by harrowing the ground after all the potatoes thrown out by the digger have been taken care of, and picking up those exposed by the harrow. The advantage of machine over hand work, however, is much less decided in handling the potato crop, whether in planting or harvesting, than in case of grain and grass crops.

WEIGHING

THE WAGON AND STOCK SCALE

The wagon and stock scale of about four tons capacity is found on many farms and is indispensable where feeding experiments are being made. With such a scale the relative weights of grain and straw may be ascertained with a fair degree of accuracy by weighing the grain in the straw on the wagon as it is being drawn to the thrasher and again weighing the grain as it comes from the machine, the weight of the straw being found by the difference.

Several plots may be carried at once by separating them with sheets, reweighing, of course, after each plot is unloaded. In the same manner several plots of hay may be brought in at once, especially if the hay sling be used for unloading.

THE PORTABLE DERRICK SCALE

The portable derrick scale is an implement much less expensive than the wagon scale and at the same time more accurate. It consists of a derrick, similar in construction to the oil or gas well derrick, but only eight feet high and correspondingly light in construction, and mounted on a pair of sled runners.

This derrick scale is especially useful in weighing the corn crop where it is husked in the field, as it may follow the huskers, weighing the stover before it is reshocked, and by means of a light platform or large basket, substituted for the hay sling, weighing the grain as it goes into the wagon. It may also be similarly used for weighing potatoes as they are harvested.

THE DERRICK SCALE

Fig. 17. The sled runners are oak joists two inches thick, ten inches wide and eight feet long; the uprights are of any strong wood two by four inches and eight feet long; at the top they are bolted to a headpiece six inches thick, eight inches wide and eighteen inches long. The swivel or rowlock which carries the pole is made by blacksmith, the ears being one-half inch by two inches, and the tongue one and one-quarter inch in diameter by eight inches long. The swivel rests upon a washer let into the headpiece, and the split key which holds the swivel in place works upon a similar washer fitted in the lower side of the headpiece. The pole is twenty-four feet long and four inches in diameter at the swivel.

REWEIGHING

The most careful people make mistakes sometimes, and the produce of every plot in experimental work—at least the grain and potatoes—should be weighed the second time. To accomplish this the grain as it comes from the thresher is weighed into sacks; these are tagged with the number of the plot and set aside, to be weighed again when there is less hurry than while the threshing is in progress. In a similar manner potatoes and corn may be gathered into tagged sacks, boxes or barrels, and weighed again. Both potatoes and corn should be separated into large and small, and in the case of corn it is advisable to count the ears, nubbins and stalks, separating these into those which bear one ear, those having two ears and those which are barren.

KEEPING THE RECORDS

PLANS, DIAGRAMS, ETC.

Before a field experiment is begun the land available should be carefully measured and a diagram of the experiment drawn to scale on paper. In connection with this diagram there should be a record book in which should be entered the dates of all operations and other items bearing upon the progress of the experiment, including the final outcome. It is never safe to depend upon memory nor upon field stakes for the plan of the experiment; for memory is proverbially treacherous and stakes are liable to be misplaced or lost. A very convenient way of entering the final results of an experiment which is continued from year to year is shown in the accompanying transcript from an actual record.

TABLE II. METHOD OF RECORDING PLOT WORK

Wheat grown in 5-year rotation of corn, oats, wheat, clover and timothy.

Plot 11	YIELD PER ACRE						INCREASE PER ACRE					
	GRAIN-BUSHELS			STRAW-POUNDS			GRAIN-BUSHELS			STRAW-POUNDS		
	Season	Total	Ave.	Season	Total	Ave.	Season	Total	Ave.	Season	Total	Ave.
1894	18.54	....	....	3,087	....	....	—0.42	....	....	991	....	....
1895	10 83	....	....	860	....	....	7.83	....	....	657	....	....
1896	9.04	....	....	1,057	....	....	7.76	....	....	784	....	....
1897	30.58	68.99	17.25	3,665	8,669	2,167	20.75	35.92	8.98	2,642	5,084	1,268
1898	33.67	102.66	20 53	3,110	11,779	2,356	17.71	53.63	10.73	1,581	6,655	1,331
1899	22.83	125 46	20.91	2,580	14,359	2,393	17.19	70.82	11.80	1,825	8,480	1,413
1900	11.67	137.13	19.59	1,120	15,479	2,211	10.67	81.49	11.64	977	9,457	1,351
1901	27.25	164.38	20.55	3,565	19,044	2,380	21.31	102.80	12.85	2,778	12,235	1,529
1902	37.33	201.71	22.41	2,710	21,754	2,417	26.97	129.77	14.42	2,045	14,280	1,587
1903	38.25	239.96	24.00	3,405	25 159	2,516	17.95	147.72	14.77	1,777	16,057	1,606

Under "season" is entered the yield for each successive year; under "total" is carried forward the aggregate yield for the entire period up to the date of entry, and under "average" is entered the average yield for the same period.

CORRECTING RESULTS

While it is highly desirable that an experiment should be sc conducted that its results may be accepted just as they come from the field, there will sometimes be cases where some correction is needed in order to avoid a statement that would be actually misleading. In the case of corn and potatoes especially it is practically impossible to secure at all times a perfect stand, because of destruction of occasional plants by insects or from other causes. Where such cases occur it has been found better to count the hills or plants and make the corrections on the basis of the average stand actually attained, rather than upon that of the possible full stand. The former method gives results corresponding to the yield actually obtained, whereas the latter one always gives exaggerated results, since it appears that the destruction of a plant gives opportunity for surrounding plants to develop more freely and produce a yield larger than could have been obtained under normal conditions.

Fig. 18. Plan of experiment with fertilizers on corn, oats, wheat and clover, grown in 4-year rotation. Four sections, of ten plots each, in the test. Fertilizers applied to corn, oats and wheat. Plots 8 and 9 manured and fertilized only on corn.

Plot	Treatment	Total constituents in 4 years
1.	Unfertilized	
2.	Acid phosphate, 160 lbs per acre	P_2O_5=68 lbs.
3.	Acid phosphate, 160 lbs. per acre Muriate of potash, 40 lbs. per acre	P_2O_5=68 lbs. K_2O =60 lbs.
4.	Unfertilized	
5.	Acid phosphate, 160 lbs. per acre Nitrate of soda, 80 lbs. per acre	P_2O_5=68 lbs. N=38 lbs.
6.	Acid phosphate, 160 lbs. per acre Muriate of potash, 40 lbs. per acre Nitrate of soda, 80 lbs. per acre	P_2O_5=68 lbs. K_2O =60 lbs. N=38 lbs.
7.	Unfertilized	
8	Barnyard manure, 6 tons per acre	P_2O_5=40 lbs. K_2O =60 lbs. N=60 lbs.
9	Barnyard manure, 5 tons per acre Acid phosphate, 200 lbs. per acre	P_2O_5=68 lbs. K_4O =60 lbs. N=60 lbs.
10.	Unfertilized	

CALCULATING INCREASE

An old soil which, from surface indications, is apparently uniform, may nevertheless show considerable variations due to previous treatment. This is shown by the accompanying diagram (Fig. 19), which shows the average yield of four plots which have received for ten years fertilizers containing the same quantities each of nitrogen, phosphorus and potassium, together with the yield of three adjoining unfertilized plots, the plots being arranged as indicated by the numbers. It will be seen that where we assume the variation between consecutive unfertilized plots to be uniformly progressive we get a practically uniform increase from the different fertilizers, but if we should strike a general average of all the unfertilized plots there would be no consistency in the results. The variation in the unfertilized yield in this case was due to the fact that the land occupied by Plot 28 and parts of the adjacent plots was not brought into cultivation until many years after that occupied by the other plots of the series; but about seven years before the test began all had been thrown into the same field, and when the test began there was no superficial indication of previous differences in treatment.

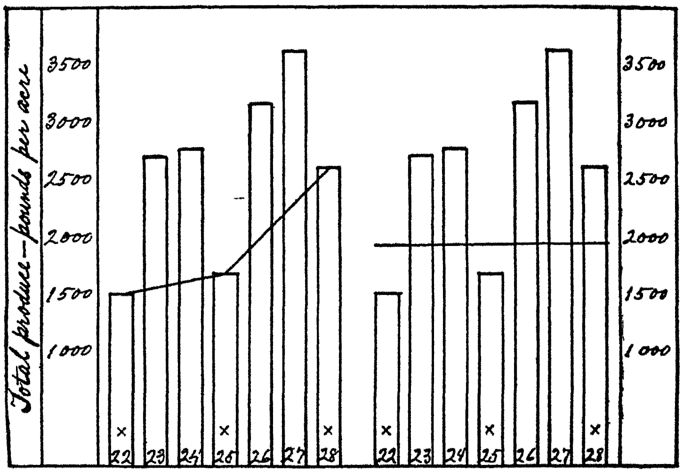


Fig. 19. When every third plot is a check plot the difference in yield between the two successive checks is found, and one-third of this difference is added to the smaller yield of the two checks or subtracted from the larger yield, the result being assumed to be the *natural* yields of the two plots lying between the checks. The difference between this assumed yield and the yield actually obtained is taken as the increase or decrease resulting from treatment.

CONTINUITY OF WORK

Few of the questions which demand solution by field experiment can be definitely answered by a single season's test. The unequal effect of rainfall on soils differently situated with respect to natural drainage may produce wide differences in the apparent results of a test in different seasons. Other climatic variations may produce similar variations in results, so that an experiment must be carried through a number of seasons before its results can be accepted as a reliable guide.

This point is illustrated by a test showing the increase or decrease in yield of wheat on several plots in 1894, and in the average for ten years. It will be observed that in the general average acid phosphate and nitrate of soda are the most effective constituents of the fertilizer, but that their effect has varied greatly in different seasons, acid phosphate producing an actual loss of crop in 1894. Had this experiment been limited to a single test in 1894 it is evident that a wholly erroneous opinion of the effect of acid phosphate on this soil would have been formed.

Tables III, IV and V show the varying effect of fertilizers over a long period of years on poor soil and on good soil. In most of these seasons phosphorus is unmistakably the chief agent in producing increase of crop; but in 1894, on the poor land, potassium takes the leading place, and in 1903 nitrogen comes to the front, while on the good land there has been still greater variability in the apparent effect of the three fertilizing constituents.

Another reason for continuity of work in experiments with fertilizers is the fact that the full effect of such fertilizers is seldom realized in the crop to which they are applied. This point is shown by Table VI, giving the average increase from fertilizers in a test which has been in progress for ten years, the figures opposite each year being the average result for the entire period up to and including that season. In this case there was a comparatively steady yield on the unfertilized plot, with a constantly increasing yield from the fertilizers.

TABLE III. EFFECT OF FERTILIZERS ON WHEAT IN DIFFERENT SEASONS.

Wheat in rotation with corn, oats and timothy on poor soil.

PLOT	FERTILZERS	INCREASE (×) OR DECREASE (—) IN BUSHELS PER ACRE	
		1894	10-YEAR AVERAGE
2	Acid phosphate	—2.80	× 6.48
3	Potassium chlorid	×5.63	× 1.25
5	Sodium nitrate	—1.22	× 1.82
6	Acid phos. and nitrate	—4.65	×11.40
8	Acid phos. and potassium	—1.11	× 8.26
9	Mur. potash and nitrate	×3.53	× 2.38
11	Acid phos., potassium and nitrate	—0.42	×14.77
12	" " " " "	×0 42	×15.92
14	" " " " "	—1.42	×13.01
15	" " " " "	—1.25	×12.42
23	" " " " dried blood	—0.06	×11.70
24	" " " " sulphate ammonia	×0.89	×11.33
26	Bone meal, potassium and nitrate	—3.06	×11.70
27	Dissolved bone black, potassium and nitrate	—5.36	×14.37
29	Basic slag, potassium and nitrate	—2.08	×13 30

1894 was the first year of the test and was the only season of the eleven years ending with 1904 when the combination of acid phosphate and nitrate of soda failed to produce a large increase.

Table III shows a decrease in yield on all plots fertilized with acid phosphate in 1894 except two. Plots 12 and 24, where acid phosphate, used in combination with other fertilizing materials, shows a slight increase, the gain however being so small as to be almost negligible, yet in the 10-year average acid phosphate has evidently been the most effective of the three materials used in producing increase of crop.

Table IV shows the varying effect of different fertilizing constituents in successive seasons on *poor* soil.

TABLE IV. EFFECT OF FERTILIZERS ON WHEAT IN DIFFERENT SEASONS

Wheat in rotation with corn, oats, clover and timothy on poor soil.

YEAR	YIELD AND INCREASE IN BUSHELS PER ACRE				
	Unfertilized Yield	INCREASE OR (*) DECREASE OVER UNFERTILIZED YIELD FROM—			
		Acid Phosphate Plot 2	Potassium Chloride Plot 3	Sodium Nitrate Plot 5	Plots 2, 3 and 5 combined
1894	19 29	*2.80	5.63	*1.22	* .42
1895	2 98	4 69	*1.02	1.42	7.83
1896	1 06	3 10	.74	.48	7.76
1897	10.43	7.02	1.81	4.83	20.75
1898	12 63	3 70	1.05	2.21	17.71
1899	6.86	5.92	1.91	1.94	17.19
1900	1.08	10.62	.55	1 20	10.67
1901	5.90	17.25	* .17	.11	21.31
1902	10.55	13 06	2.86	1.75	26 97
1903	18.34	2.16	* .83	5.50	17 95
Average.......	8.91	6.48	1.25	1.82	14.77

Injury from Hessian Fly in 1895, 1896, 1899, 1900 and 1901.

Table V shows the varying effect of different fertilizing constituents in successive seasons on *good* soil.

TABLE V. EFFECT OF FERTILIZERS ON WHEAT IN DIFFERENT SEASONS.

Wheat in rotation with potatoes and clover on good land.

YEAR	YIELD AND INCREASE IN BUSHELS PER ACRE				
	Unfertilized Yield	INCREASE OR DECREASE (*) OVER UNFERTILIZED YIELD FROM—			
		Acid Phosphate Plot 2	Potassium Chloride Plot 3	Sodium Nitrate Plot 5	Plots 2, 3 and 5 combined
1895	7.51	7.53	1.06	1 98	8 03
1896	7.42	4.52	1 56	2 63	8 14
1897	34.16	.97	3.11	3 44	8 44
1898	22.99	4.10	2 65	1 21	9.36
1899	25 88	1.53	2 39	2 25	9.75
1900	37.90	4.03	6 30	*1.45	2.33
1901	24.25	3 38	*1.10	*4.13	3.56
1902	36.23	6.83	.26	1.36	16.47
1903	26.75	3.80	*2.69	5.67	11.08
Average.......	4.14	4.19	2.10	1.43	8.57

Injury from Hessian Fly in 1895 and 1896.

Table VI shows the cumulative effect of systematic fertilizing; each season's increase being sufficient to raise the average increase for the total period to a higher level.

TABLE VI. PROGRESSIVE INCREASE FROM FERTILIZERS.

Increase in bushels per acre.

PLOT 11. COMPLETE FERTILIZER	CORN	OATS	WHEAT
Average increase for 3 years ending 1896	8 45	12 08	5 06
" " " 4 " " 1897	8.74	13 57	8 98
" " " 5 " " 1898	10.72	12.92	10 73
" " " 6 " " 1899	11.20	14 51	11 80
" " " 7 " " 1900	12 60	15 92	11 64
" " " 8 " " 1901	14 48	17 21	12 85
" " " 9 " " 1902	15 18	17 98	14 42
" " " 10 " " 1903	15 07	18.33	14 77

SUMMARY

The experiment station stands for organized research, does things impossible to the ordinary farmer, and formulates general principles. The farmer must make the application. The farmer who profits most by the experiment station must himself be an experimenter.

SELECTION OF SOIL

The *geological history* of a soil is of importance as an index to its general character. *Previous managemeut* may have an important bearing upon the results of an experiment, as shown by long-continued effect of manuring at Rothamsted. In *topography* an experiment field should not be absolutely level nor very steep; a broad, gentle slope of 1 or 2 percent, or just enough to permit uniform surface drainage, has been found best.

ARRANGEMENT OF PLOTS

The most convenient *size of plots*, for most purposes, is one-tenth acre. This size is convenient for computation, and holds a sufficient number of plants to eliminate the errors arising from individuality if care be taken in seed selection. The inequalities of soil can be better eliminated by duplicating the test in small plots than by the use of large plots. In *shape*, the plots should be long and narrow. It is well to adjust the width to the convenient use of machinery and to the scheme of drainage.

Surface drainage must be provided for, and this can be most easily done by making the plots comparatively narrow and slightly ridging them. *Underdrainage* is absolutely necessary on moist soils. *Division spaces* need not be more than 2 feet wide, provided they are the dead furrows made in ridging the plots. *Old ridges and dead furrows*, when running lengthwise of a plot, may reverse the results of a test, hence plots should be laid out across the direction of previous plowings. *Cross drainage* should be carefully avoided in fertilizer tests. *Cross feeding* may be prevented by separating the plots by dead furrows. The repetition of *check plots* is a matter of first importance. Every third or fourth plot should be used as a check. The *boundaries* of every block of experiment plots should be permanently marked with stakes that will not be thrown out in plowing. *Headlands and roadways* should be left around every block of eight or ten plots, so that teams may be turned without trampling the plots, and every plot should be distinctly marked with a label stake.

PREPARATION OF LAND FOR CROPS

Uniformity of treatments is of first importance. A difference of a few days or weeks in date of plowing may cause as great a difference in yield as any difference in variety or fertilizing. *Manures and fertilizers* should be applied by machinery with special care to get each application wholly on its plot and uniformly distributed. Lime may be applied with a special lime distributor or with manure spreader. All *machinery should be accurate*, whether for seeding, harvesting or thrashing. *Selection of seed* is a matter of importance. Seed of low vitality will not give a proper stand, nor will seed that is uneven in size, hence the tips and butts of seed corn should be rejected and the small grains should be graded. *The rows should be straight*, especially with the small grains, for when the rows crowd each other the yield will be reduced. *The entire plot should be planted*, and to accomplish this the small grains should be drilled beyond the plots, cutting away the excess before harvest.

PLANTING AND CULTIVATING

Machine work is preferable wherever it can be employed, as it is more accurate and uniform than hand work, whether for planting, cultivating, harvesting or thrashing.

HARVESTING

Grass plots may be mown by driving the machine to stakes set so that the nose of the machine will just reach the outer edge of the plot. For *harvesting grain crops* the plots should be arranged in blocks of eight or ten, with 12-feet roadways between, so that the machine may not be driven over the plots except when actually cutting. In all cases a gleaner should follow the machine, to keep the produce of each plot on the plot itself.

WEIGHING

Hay and grain may be weighed on the ordinary wagon and stock scale. Several plots may be loaded on the wagon, separating them by sheets, and weighing again after each one is unloaded; but a cheaper and better weighing arrangement is the *portable derrick scale*, a common weigh beam suspended to the shorter end of a long lever, which is pivoted on a small derrick carried on a sled and moved from place to place as needed. All weights of grain or potatoes should be verified by setting the produce of each plot aside in a tagged sack or barrel and *reweighing* at leisure.

KEEPING THE RECORDS

A complete *plan* of each experiment should be made on paper before the work in the field is begun, and every operation should be entered in a record book kept for the purpose. It is sometimes necessary to *correct the results*, and it is better to base this correction upon the average actual yield rather than the possible full yield. The *calculation of increase* should be made on the assumption that the variation between neighboring check plots is due to similar variations in the soil between them. It is never safe to assume that one or two check plots will sufficiently indicate the character of the soil of a large field, nor that the general average of a series of such plots will do so.

CONTINUITY OF WORK

This is of first importance in field experiment. The result of one season's test may be the direct opposite of the average outcome of a period of years, and as a general rule the full effect of the fertilizer or manure can only be determined after a series of years.

Plots 6 and 7 in 5-year rotation, 1905. Yield per acre: Plot 6, 21.33 bushels; Plot 7, 4.42 bushels. A part of Plot 5 is shown in the upper left hand corner, and of plots 8 and 9 in the right hand corner, with a small part of Plot 11 at the extreme right.

Plots 10 and 11 in Potatoes-wheat-clover rotation, 1906. Yield per acre: Plot 10, unfertilized, 46.46 bushels. Plot 11, complete fertilizer, 52.33 bushels.

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